9. with the Cruth as Compton

29 Upper Phillimore Place

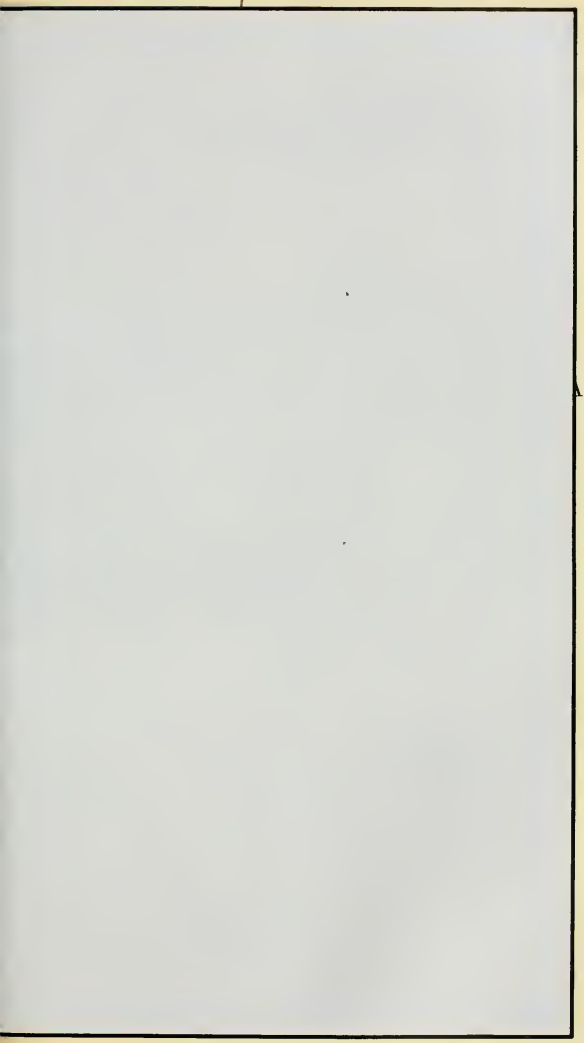
5th March

Dear Sir

I accidentally heard that you want to read my Paper on Cakes. Hunt told me. I send one of three remaining copies

Yours very truly

Andrew Ramsay



John Campbell Esq.
with the Author's Compliments

ON THE

GLACIAL ORIGIN OF CERTAIN LAKES

IN

SWITZERLAND, THE BLACK FOREST, GREAT BRITAIN, SWEDEN, NORTH AMERICA, AND ELSEWHERE.

BY

A. C. RAMSAY, F.R.S.

President of the Geological Society, &c.

[PLATE VIII.]

[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for August* 1862.]

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Contents.

Erroneous Theories of the Transport of Alpine Blocks.—In the year 1859, in a series of papers by the members of the Alpine Club, I published a memoir in which I compared the old glaciers of North Wales with those of Switzerland; and in it, among other matters, I explained the glacial origin of certain rock-basins now holding lakes, on the watersheds and in the old glacier-valleys of both those countries; and in a later edition of the same memoir, published as a separate book, with additions*, I extended these generalizations to many of the lakes in Sutherlandshire.

In the same work I also expressed an opinion that the blocks of Monthey, in the valley of the Rhone, and the great erratic boulders that strew the southern flank of the Jura had been transported by icebergs derived from glaciers which descended in the Alpine valleys to the sea-level, during a period of submergence in which the low country that lies between the Jura and the Oberland was covered with erratic drift.

There was nothing new in this latter opinion, for it had previously been held by several distinguished geologists, both English and continental.

Since then I have twice revisited Switzerland, and have seen good reason to change my opinion respecting the cause of the transport of erratic blocks to Monthey and the Jura, and of *débris* not remodelled by rivers, &c., that lies scattered over the lowlands of Switzerland, or that borders, or lies in great mounds well out in, the plain of Piedmont and Lombardy. I am now convinced, for example, that the vast circling moraine of Ivrea, noticed by Studer in 1844, was shed from a glacier, 105 miles in length, that filled the valley of Aosta to a height of more than 2000 feet, and protruded far into the plain; while on the north a still greater glacier, long ago described by Charpentier, flowed from the valley of the Rhone right across the low country until its end abutted on the Jura. As there are still many persons in England who doubt these conclusions, it

* 'The Old Glaciers of North Wales.' Longman & Co.

may not be beside the question to state the considerations that led me to reject the old theory.

Reasons for abandoning the older theories.—I first began to doubt the correctness of my earlier opinions in the summer of 1860, while examining the country near Bonn, the banks of the Moselle, and the Eifel. Neither in the valleys nor on the wide table-lands on both sides of the Rhine and the Moselle is there any sign of glacial drift. Excepting alluvial *débris* in the valleys, the native rock is generally quite bare of transported detritus; and the only marks of glaciation lie low on the sides of the Moselle, where the floating down of the river-ice has frequently rounded, polished, and striated the rocky banks in the direction of the flow. Boulders, transported from further up the stream, also sometimes lie on the shores. But, in the absence of true drift, I considered that, had Switzerland been depressed at least 3000 feet, until its mountains were washed by a sea that floated transported blocks to the higher Jura, the table-lands of Rhenish Prussia and Westphalia would also possibly have been submerged, and more or less covered with glacial detritus. Further up the Rhine and in the Black Forest the same absence of marine drift prevails. There, looking eastward towards the Rhine, the mountains, chiefly of gneiss, are wonderfully scarred, telling the observer of the wasting effects of frost, ice, rain, and rivers, probably ever since the close of the Miocene period. In the valley of Oberweiler, between Mullheim and the watershed, I observed occasional heaps of moraine-like detritus, in which by diligent searching I found a few stones marked with the familiar glacial scratchings.

In the interior towards Schonau and the Belchen, the rocks being generally soft and schistose, no very decided signs of old glaciers occur, and no part of the country shows symptoms of the presence of drift. Altogether the country looks as if it had stood in the air for so great a period that, even if glaciers were once present, they had disappeared so long that all the more prominent signs of degradation are now due to rain and running water. But further in the interior it is altogether different; for the signs of old glacier-ice are plentiful enough, and for miles round the Feldberg, which rises 4982 Baden feet above the sea, the sides of the valleys to the very summits of the mountains are often strikingly *moutonnées*, though the rounded forms are generally roughened and frequently half ruined with age. On these, striations, though rare, may occasionally be discovered (running in the direction of the valleys), although the rapid rate at which the rock weathers is much against their preservation. Moraines also are not uncommon. At the foot of the Feldberg, on the east, there is a beautiful circular lake, called the Feldsee, surrounded by tall cliffs of gneiss and granite in the shape known in Scotland as a corrie—a form eminently characteristic of all glacier-countries past or present. The outer side of the lake is dammed up by a perfectly symmetrical moraine, curving across the valley, and formed of sand, gravel, and of granite and gneiss, often in large boulders. It is now covered with pine-trees. The lake is deep, and the moraine rises from 25 to 40 feet

above the water. Outside the moraine lies a flat marsh, still retaining traces of having been a lake, once also dammed by a second and outer moraine, formed chiefly of large angular blocks of gneiss, piled irregularly on each other like the old moraine of Cwm Bochlwyd, above Llyn Ogwen in Caernarvonshire. Quantities of moraine-matter strew the valley for two or three miles further down to the little marshy lake at Waldbauer, which is also dammed up by moraine-rubbish, in one place rudely stratified, like some of the old moraine-heaps on the Jura and parts of the great moraine of Ivrea; or like the heaps of glacier-*débris* that often border the lakes marshes, and flat peat-mosses, once lakes, that diversify the lowlands of Switzerland. At the upper end of the Alb Thal also, at the entrance of Menzenschwanden Alb, I saw four moraines curving across the valley, arranged concentrically one within another, like those at the end of the glacier of the Rhone; and for many miles in the Alb Valley, both above and below St. Blasien, *roches moutonnées* stand like islands through the alluvium, while it is also plain that the sides of the mountains above have been to a great height smoothed by ice. Nowhere however down to Allbruck, where the river joins the Rhine*, did I see any "drift;" and this village lying close on the north side of the Jura, it seemed impossible that the higher ground on the south side of that range, between the Lakes of Constance and Geneva, should have been submerged during any part of the Glacial period, while the country on the Rhine above Basel remained above the sea. I therefore saw that the theory that the *Pierre à bot* and its companion blocks had been floated from the Alps by marine icebergs was untenable; and a later examination of a portion of the Jura, partly under the able guidance of Professor Desor, fully convinced me that the ice that descended the great valley of the Rhone had covered much of the low country and abutted on the south-eastern flank of the Jura.

Old Distribution of the Great Alpine Glaciers.—At that period, then, of extreme cold, when the glaciers of the Alps flowed right across the Miocene basin of Switzerland, a glacier of vast thickness (No. 1 on the Map, Pl. VIII.), running from end to end of the upper valley of the Rhone, debouched upon the lowlands at what is now the eastern end of the Lake of Geneva, and spreading in a great fan-shaped mass extended to the south-west several miles down the Rhone below its present outflow from the lake, and north-east to the banks of the Aar, about half-way between Solothurn and Aarau. The length of this fan-shaped end of the glacier, from north-east to south-west, was about 130 miles, and its extreme breadth about 25 miles. Another great glacier (No. 5) descended in a direction opposite to the higher part of the Rhone glacier, through the upper valleys of the Rhine, and debouched upon a wide area that extends from Kaiserstuhl on the Rhine, far to the north-east. In the centre of this area lies the Lake of Constance. Between these, which were the largest glaciers on the north watershed of the Swiss Alps, several smaller, but still enormous, glaciers flowed in a north-westerly direction from the

* Between Basel and the confluence of the Aar and the Rhine.

mountains,—one down the Linth, through the area now occupied by the Lake of Zurich (No. 4), another down the Upper Reuss, across the area in which lie the Lakes of Lucerne, Zug, and others (No. 3), and a third down the valley of the Aar to Berne, through the country that now contains the Lakes of Brienz and Thun (No. 2). According to this view (the result of the researches of the best Swiss geologists), the greater part of the Swiss Miocene area lay deep under ice*, and I am inclined to think that the country between the great old glaciers of the Reuss, Aar, and Rhone was much more covered with ice than any map shows, the whole helping to swell the prodigious glacier of the Rhone that abutted on the Jura.

Connexion between Tarns and Glaciers.—In 'The Old Glaciers of North Wales' I have shown that in all glacier-countries, whether past or present, there is an intimate connexion between tarns and glaciers. Some of these are dammed by old moraines†, but the greater number lie in *rock-basins*, formed by the grinding of glacier-ice as it passed across the country, whether in valleys, on rough table-lands, or on the watersheds of passes. These lakes and pools are of all sizes, from a few yards in width, lying amid the mammillations of the *roches moutonnées*, to several miles in diameter. Sometimes in the convolutions of the strata (conjoined with preglacial denudation subsequent to the contortion of the beds), softer parts of the country may have been scooped out, leaving a hollow surrounded by a framework of harder rock; but perhaps more generally they were formed by the greater thickness and weight, and consequently proportionally greater grinding pressure, of glacier-ice on particular areas, due to accidents to which it is now often difficult or impossible to find the clue. Trifling as this phenomenon at first sight may seem, I yet believe the manner of the formation of these lakes is of much importance to the right understanding of the glacial theory, whether taken in connexion with the great extension of extinct glaciers in recognized glacier-regions, or, further, when viewed on a general continental scale; for *the theory of the glacial origin of many rock-basins* must, I feel convinced, be extended much beyond such mountain-districts as Switzerland, Wales, and the Highlands of Scotland, where they first attracted my attention ‡.

Origin of the Great Alpine Lakes. Subject stated.—From the consideration of the origin of mountain-lakes and tarns, the question easily arises,—What are the causes that have operated in the formation of the great lakes of Switzerland, such as those of Geneva, Zurich, and Constance, and, south of the Alps, of Maggiore, Lugano, Como,

* The limits of the northern glaciers on the Map (Pl. VIII.) are chiefly given from a MS. map compiled by M. Morlot. Those on the south are taken from a map by M. de Mortillet. Both were lent me by Sir Charles Lyell.

† Quart. Journ. Geol. Soc. 1851, vol. viii. p. 371; and 'Old Glaciers of North Wales.'

‡ It is not to be supposed that I attribute the origin of all rock-basins to glacial action. Many lie in the craters of extinct volcanos, some, no doubt, in areas of special subsidence, and others may be due to causes of which I know nothing. I now confine my remarks to certain lakes common in all highly glaciated regions such as I know.

and others? To answer this with precision, it will be necessary, first, to examine several other hypotheses that by some may be thought sufficient to account for them.

It is well known that after the close of the Miocene epoch the rocks of the Alps were much disturbed,—a circumstance proved by the contortion of the Miocene strata, as for instance in the neighbourhood of Lucerne, where, on the Rigi (and in other conglomeratic mountains on the same strike), the strata are considered by the best Swiss geologists to be repeatedly folded and fairly inverted, so that the basement-beds form the top of the mountain instead of its bottom, thus, by reversal of dip, plunging under the Eocene and Cretaceous strata of the mountains further south. The whole, as shown by the rapid truncated foldings and the escarpments of the hills, has since been much denuded, the denudation being of a kind and amount that, to effect it, proves the lapse of a long period of time. Witness the outliers of Miocene strata in the upland valleys of the Jura. Among these disturbed and denuded strata of Miocene and of older dates, the Lakes of Geneva, Thun, Brienz, Lucerne, Zurich, Constance, the Wallen See, and the great lakes of North Italy lie. A knowledge of the stratigraphical structure of the Alps, in my opinion, proves that these lakes do not lie among the strata in basins merely produced by disturbance of the rocks, but in hollows due to denuding agencies that operated long after the complicated foldings of the Miocene and other strata were produced.

First, none of these lakes lie in simple synclinal troughs. It is the rarest thing in nature to find an anticlinal or a synclinal curve from which some of the upper strata have not been removed by denudation. I never yet saw a synclinal curve of which it can be proved that the uppermost stratum in the basin is the highest layer of the formation that was originally deposited over the area before the curving and denudation of the country took place. The only approach to this may possibly be in the upper valleys of the Jura, where a part of the Miocene beds lie in basins separated by secondary anticlinally curved strata, the tops of the anticlinal bends having been removed by denudation; but these cases are surrounded with difficulties. The lake-hollows in the Alps are, however, encircled by rocks, the strikes, dips, and contortions of which often exhibit denudation on an immense scale; and in no case is it possible to affirm, here we have a synclinal hollow of which the original uppermost beds remain. If these beds have disappeared to a great extent, then it is evident that denudation has followed disturbance. The fragmentary state of the uppermost Miocene strata of the lowlands of Switzerland proves this denudation. Again, if it be argued that in the lake-areas these denudations have been produced by the waters of the lakes, it is replied that, though waves may form cliffs, neither running nor still water can scoop out deep trough-shaped hollows.

Secondly, the same kind of argument applies to areas of mere watery erosion by rivers. Running water may scoop out a sloping valley or gorge, but (excepting little swallow-holes) it cannot form and deepen a profound hollow, so as to leave a rocky barrier all

round; though it may fill with sediment one that had previously been formed.

Thirdly, neither do most of the Swiss lakes lie in lines of dislocation. For many reasons I do not believe that any one of them among the high Alps or on their flanks can be proved to lie in lines of mere gaping fracture. Let us consider the nature of such fractures.

In any country where the strata are comparatively little disturbed and lie nearly horizontally, if it be faulted, there is no reason why the fractures should be open. In the Oolites, for example, in the South of England, where faults are numerous, and in the New Red Sandstone of the central counties, there is generally a simple displacement of the strata up or down, on one side or the other; or, if the disturbance go beyond this, it is that along the sloping line of fracture the beds on the downthrow side are turned up, and those on the opposite side bent down, by pressure and slipping combined. In more disturbed districts, like the Welsh Coal-measures, the same phenomena are observable: witness, for instance, the numerous sections from accurate observation, drawn on a true scale, by Sir Henry De la Beche, Sir William Logan, and others. Experience both above ground and in mines proves the same. Most lodes are in fractures, and many lie in lines of fault. In metamorphic, excessively contorted, and greatly fractured districts like those of Devon, Cornwall, and Wales, the cracks, whether bearing metals or not, vary from mere threads to a few fathoms in width. They are always filled with quartz or other foreign substances, frequently harder than the surrounding matrix. I have often traced lodes on the surface, in Wales, by the hard matter filling the crack standing in relief above the surface of the softer enclosing rock. In limestone rocks the cracks are usually partly filled with crystallized carbonate of lime. Lines of fracture are not, therefore, for purposes of denudation, necessarily lines of weakness, unless it happen that on opposite sides of the fault hard and soft rocks come together, when of course the softer rocks will wear away more rapidly, and generally originate a straight valley.

Again, in an excessively contorted country, such as the Alps, it is, I believe, impossible, *in consequence of that contortion*, that there should be gaping fractures now exposed to view. Assuming for the sake of argument the sudden violent contortion of the strata of any great tract of country, we shall see that the contorted rocks *now exposed at the surface*, even if broken, would be most unlikely to gape.

The expression "elevation of mountains" conveys to the minds of many persons the idea that the elevation has been produced by some force acting from below, along a line in the case of a chain, and on a point of greater or less extent when the mountains lie in a cluster, as a whole, more or less dome-shaped. Such forces would stretch the strata; and when they could no longer stand the tension, cracks would ensue, and many lines of valley are assumed to lie in such fractures. But in Wales, the Highlands of Scotland, and more notably in the Alps, the strata now visible have been compressed and crumpled,

not stretched, and they occupy a smaller horizontal space than they did previous to the formation of the chain.

Let us suppose a set of strata of (say) 14,000 to 20,000 feet in thickness, like the rocks of North Wales, and let these be spread out horizontally over thousands of square miles. Let these strata, from any cause, be compressed from the right and left so as to be contorted, and occupy a smaller horizontal area than they did before disturbance. Then, at a great depth, where the superincumbent strata pressed heavily on the lower beds, the latter would be crumpled up, cleavage would often supervene, and gaping fractures would be impossible; for, where mere fractures occurred, the walls of the cracks would be pressed more closely together. But nearer the surface, where there was less weight, and at it, where there was none, the beds would extend into larger curves than they did lower down; and where the limits of extensibility were passed, shattering might take place, and yawning chasms might ensue. In all violently contorted countries, however, as in the cleaved rocks of North Wales, for instance, the present surface shows those originally deep-seated contortions that since disturbance have been exposed by denudation; otherwise the rocks would not be cleaved. I therefore do not believe that in any country I have seen, such as Wales or Switzerland, there are any lakes now occupying yawning fractures, consequent in Switzerland on post-eocene or post-miocene disturbances. On the contrary, they lie in hollows of denudation, shortly to be explained, of later date than these disturbances.

Fourthly, again, it may be supposed that the great lakes lie each in an area of special subsidence; but, in reply to this, it is evident that among the unnumbered lakes of Switzerland and the Italian Alps it would be easy to show a gradation in size, from the smallest tarn that lies in a rock-basin to the Lakes of Geneva and Constance. Neither do I see any reason why mere size should be considered the test of subsidence. Disallowing that test, we should require a great number of special subsidences, each in the form of a rock-basin, in contiguous areas. Between the Seidelhorn and Thun, for example, we should require one for the Todten See, several on the plateau on the north immediately under the Seidelhorn, one for the lake at the Grimsel, another for the drained lake at the Kirchet*, and another for the lakes of Brienz and Thun. In Sutherlandshire these areas of special subsidence would be required by the hundred, and in North America by the thousand.

Signor Gastaldi, in a masterly memoir on the composition of the Miocene conglomerates of Piedmont†, considers with reason that the large angular blocks of these strata, many of them far-transported, and some of them foreign to the Alps and Apennines, have been deposited from ice-rafts; and thence he infers the existence of glaciers during a part of the Miocene epoch. But, admitting this, it is evident that the distribution of the post-pliocene glaciers of

* See the "Old Glaciers of Switzerland and North Wales."

† "Sugli elementi che compongono i conglomerati Mioceni del Piemonte." Turin, 1861.

the Alps must, in all details, have been quite different from those of Miocene age, in consequence of the great disturbance that the Alpine rocks underwent after the close of the Miocene epoch, and the subsequent formation of numerous new valleys of denudation. Traces of the long lapse of time between the Miocene and the later Glacial epoch are in other countries but imperfectly preserved in the subdivisions of the Crag, and of other minor formations of still later date. Of the finer gradations that unite these subdivisions few traces have been described. For long before, and during all these Crag epochs and the ages between them, of which we have little trace, and during all the time that elapsed from the close of the Crag until the period of extreme cold came into action, the Alps stood above the sea, and, suffering subaërial denudation, valleys were being formed and deepened. It is possible that, while the mild climates of the Lower Crag epochs endured, there may still have been glaciers in the higher Alps; but at whatever period the later glaciers commenced, those who allow the extreme slowness of geological change will admit that the period was immense that elapsed during the gradual increase of the glaciers, until, in an epoch of intensest cold, the ice abutted on the Jura in one direction, in another spread far beyond the present area of the Lake of Constance, and on the south invaded the plains of Lombardy and Piedmont. During all that time weather and running water were at work modifying the form of the ground under review. But, as I have already explained, these two agents were incapable of scooping out deep hollows surrounded on *all* sides by rocks, and it therefore follows that the lakes first appeared after the decline of the glaciers left the surface of the country exposed approximately as we now see it,—unless we admit, what seems to me impossible, that fractures, formed at the close of the Miocene epoch, remained filled with water until the great glaciers filled them with ice; or believe, with De Mortillet, that the valleys and lake-hollows were charged with waterborne alluvial or diluvial *débris* before the glaciers ploughed it out *.

Allowing the hypothesis of De Mortillet, the rock-basins must have been twice filled with water; but, according to my hypothesis, they did not exist as lakes till after the disappearance of the glaciers.

But the glacier map of ancient Switzerland shows that the areas now occupied by the great lakes, both north and south of the Alps, have all been covered with glaciers. No tertiary deposit of an age between the close of the Miocene and the commencement of the Glacial epoch lies between the Alps and the Jura; and, had the hollows of the lakes existed prior to the great Glacial epoch, we ought, but for some powerful wasting agent, probably in these hollows, still to find

* See an admirable memoir by G. de Mortillet, "Des Anciens Glaciers du Versant Italien des Alpes." Milan, 1860. Though I had seen his map, I had not seen this memoir when I read my paper; and the passages in which it is mentioned have been added as these pages passed through the press. His theory leaves the difficulty of the first formation of the basins untouched, unless we believe (which I do not) that the Alpine valleys are lines of fracture.

some traces of freshwater deposits, perhaps of the age of part of the Crag. No such relics exist.

The Great Lakes. Lake of Geneva.—The Lake of Geneva is about 45 miles in length by about 12 in breadth, and its delta, once part of the lake, between Villeneuve and Bex, is 12 miles long. The latter and a small part of the banks of the lake beyond the mouth of the river lie in the great Rhone valley, formed of older Tertiary and Secondary rocks. All the rest of the lake is surrounded by the low country formed of the various subdivisions of the Molasse and Nagelfluh. The lake is 1230 feet above the level of the sea, and 984 feet deep towards the eastern end, according to the soundings of De la Beche *. See fig. 1, p. 194.

Geneva itself stands on superficial *débris*; but the solid rock first appears in the river-bed below Geneva, at Vernier, at the level of 1197 feet above the sea—only 33 feet below the surface of the lake, or 951 feet above the deepest part of its bottom. Any one acquainted with the remainder of the physical geography of the country will therefore see that the water of the lake lies in a true rock-basin. The question thus arises, How was this basin formed?

1st. It does not lie in a simple synclinal basin; for, though the Lake of Geneva lies in the great synclinal hollow of the Miocene strata between the Alps and the Jura, it is evident by an inspection of the country that the flexures of that formation are of far greater antiquity than the lake. These flexures have been denuded, and the lake runs in a great degree across their strike.

2nd. For reasons already stated, it is, I believe, impossible to prove that the lake lies in an area of special subsidence, all the probabilities being against this hypothesis.

3rd. It is almost needless to say that the Lake of Geneva is too wide to lie in a mere line of fracture; and I know of no reason why the valley of the Rhone, where occupied by the delta, should be esteemed a line of fault or gaping fissure, any more than many other valleys in Switzerland, which many geologists will consider with me chiefly the result of the old and long-continued subaërial denudation of highly disturbed strata. I could enter on details to prove this point, but they belong rather to the rock-geology of Switzerland than to the matter in hand.

4th. Those who do not believe in the existence and excavating power of great and sudden cataclysmal floods will at once see that the area of the lake cannot be one of mere watery erosion; for ordinary running water, and far less the still water of a deep lake, cannot scoop out a hollow nearly 1000 feet in depth.

Now, if the Lake of Geneva do not lie in a synclinal trough, in an area of subsidence, in a line of fracture, nor in an area of mere aqueous erosion, we have only one other great moulding agency left by which to modify the form of the ground, namely, that of ice.

When at its largest, the great glacier of the Rhone (No. 1 of the Map, Pl. VIII.) debouched upon the Miocene beds where the eastern end of the Lake of Geneva now lies. The boulders on the Jura, near

* Edinburgh Philosophical Journal, 1820, vol. ii. p. 107, and plate 2.

Fig. 1.—*Outline-map of the Lake of Geneva, showing the rincipal Soundings in English feet. (After Sir H. De la Beche, F.R.S.)*

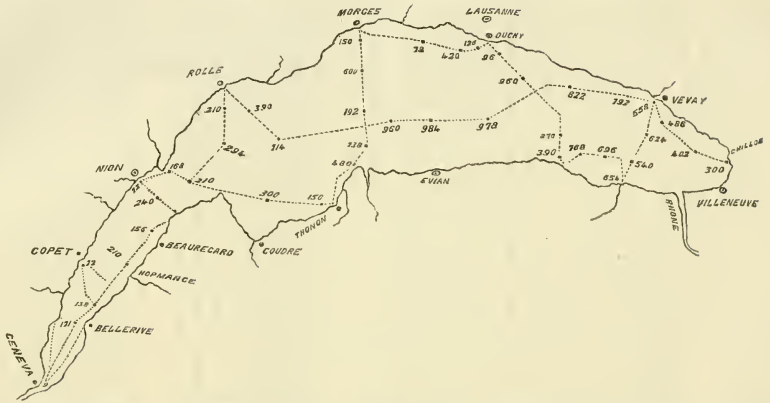
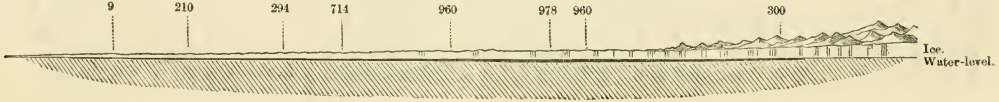


Fig. 2.—*Diagram-section of the Lake of Geneva, with Soundings in English feet, and showing the Comparative Thickness of the Ice of the Old Glacier.*



Neuchâtel, at the point on the Map marked B, prove that this glacier was about 2200 feet thick where it abutted on the mountains; and, where it first flowed out upon the plain at the mouth of the valley of the Rhone, the ice, according to Charpentier, must have been at least 2780 feet thick *. Add to this the depth of the lake, 984 feet, and the total thickness of the ice must have been about 3764 feet at what is now the eastern part of the lake, fig. 2†. I conceive, then, that this enormous mass of ice, pushing first north-west and then partly west, scooped out the hollow of the Lake of Geneva most deeply in its eastern part opposite Lausanne, where the thickness and weight of ice, and consequently its grinding power, were greatest. This weight decreasing as it flowed towards the west, from the natural diminution of the glacier, possessed a diminishing eroding power, so that less matter was planed out in that direction, and thus a long rock-basin was formed, into which the waters of the Rhone and other streams flowed when the climate ameliorated and the glacier retired.

Lake of Neuchâtel.—The basins of the Lakes of Neuchâtel, Bienne, and Morat were, I consider, hollowed out in a similar manner, differing in points of detail. Near the Lake of Neuchâtel, on the flank of the Jura, the fan-shaped end of the Rhone glacier (No. 1) attained its greatest height, swelled in size and pressed on as it was by others that descended from the north snow-shed of the mountains between the Oldenhorn and the great snow-field above Grindelwald. According to estimates based on the highest ice-stranded boulders, the ice rose 2203 feet above the present surface of the lake. The lake is now 1427 feet above the sea, and 480 feet deep; and the Lake of Bienne is 1425 feet above the sea, and 231 feet in depth. The bottom of the Lake of Neuchâtel is thus 947 feet above the sea. Unless the gravel, therefore, on the banks of the Aar, immediately east of the latter, be over 480 feet deep, the hollow of the lake near its immediate bounds is a true rock-basin; for on the north, south, and west it is surrounded by solid Secondary and Miocene rocks. Even if the rock does not rise close to the surface in the river near the lake, still, at Solothurn, strata in place come close to the river-bank on both sides, the river being 1414 feet above the sea. Under any circumstances there must therefore be a long, deep trough between Solothurn and the rocks a little south-west of the Lake of Neuchâtel. How was this basin formed? When the glacier, debouching from the valley of the Rhone, spread out like a fan and pressed forward till it abutted on the Jura, its onward progress was stopped by that mountain; and direct further advance being hindered, the ice spread north-east and south-west, to the right and left, and being as a whole thickest and heaviest above the area where the lake now lies, a greater quantity of the Miocene strata on which it rested must have been ploughed out there than further on towards the north-east and south-west ends of the glacier, towards which

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* The Lake of Geneva is 197 feet lower than the Lake of Neuchâtel. The glacier first surmounted the hills between Lausanne and Vevay, and then flowed down the general slope northwards to the Jura.

† This diagram is on a true scale both horizontally and vertically.

the ice, gradually declining in thickness, exercised less grinding power. In this manner I believe the troughs were formed in which lie the three lakes near Neuchâtel; and when the ice finally retreated, the ordinary drainage of the country filled them with water, the cliffs on the south-eastern side of the Lake of Neuchâtel and other changes of the form of the ground having since been produced or modified by watery erosion and the local deposition of silt and alluvial gravel.

The Lake of Thun.—The Lake of Thun is 1825 feet above the sea, and 776 feet deep. Its bottom is therefore 1049 feet above the sea. It is about 10 miles in length, $1\frac{1}{2}$ broad, and its length chiefly cuts across the strike of rocks of Secondary and Miocene age. The Lake of Brienz (about the same size) is more remarkable; for, while its level is 1850 feet above the sea, its depth is more than 2000 feet: so that its bottom is at least between 100 and 200 feet below the level of the sea. Before the formation of the alluvial plain between, these two lakes were probably united; and whether or not this was the case, it is evident, from its great depth, that the Lake of Brienz lies in a true rock-basin. Even if below Thun the rocks do not crop nearer than Solothurn, the Lake of Thun still lies in a rocky hollow more than 600 feet deep, both hollows having, I believe, been deepened by the great old glacier of the Aar (No. 2 in the Map), the ice of which was so thick, that above Brienz it overflowed into the valley of Sarnen by the Brunig, about 1460 feet above the Aar below Meyringen, and sent off a branch which scooped out the hollows of the Lakes of Lungern and of Sarnen on its course towards Alpnach on the Lake of Lucerne.

The Lake of Zug.—The Lake of Zug is about 9 miles long, from 1 to $2\frac{1}{2}$ wide, 1361 feet above the sea, and 1279 feet deep; and its bottom is therefore only 82 feet above the sea. The whole is surrounded by Miocene strata, the strike of which the lake cuts across, and its great depth clearly shows that it lies in a rock-basin.

The Lake of Lucerne.—The Lake of the Four Cantons (Lucerne) ramifies among the mountains and extends its arms in various directions. In its lower part, the branches that run N.E. to Kussnach and S.W. towards Gestad lie partly in the strike of the Miocene and older strata; but for the most part it runs across the average strike of the Eocene and Secondary rocks, between banks, sometimes precipitous, that rise in noble cliffs sometimes more than 2000 feet above the water. Its height is 1428 feet above the sea, and its recorded depth 853 feet; but the shape of the banks and the round number of 800 French feet make it likely that it may contain deeper gulfs than have yet been plumbed. If not, then its bottom is 575 feet above the sea; and those acquainted with the shape of the ground by Lucerne will easily be convinced that the lake lies in an actual rock-basin. The steepness of the walls of this lake more resembles the sides of a rent than those of any of the basins yet described, and the re-entering angles of rock opposite curving bays have been cited as evidences of fracture, one side being supposed to fit into the other. But in most cliffy valleys of aqueous erosion there

are necessarily such re-entering angles, from the common action of running water; and, in Switzerland, ere these valleys were filled with ice, they existed in some shape, and were drained by rivers that deepened them and gave them a general form preparatory to the flow of the ice that largely modified their outlines. I should no more consider the re-entering angles a sign of gaping fracture in these valleys than I would the bends of the Welsh valleys or of the tortuous Moselle. But even if at first sight one were inclined to believe the space between the opposite cliffs between Brunnen and Flühlen to be an open fracture, if we take a moderate average slope for each side, say of 65°, and produce it below the water, we get a depth, ere the lines meet, of between 7000 and 8000 feet—a very improbable depth for the original hollow of the lake. But it may be said that the fracture has been much widened by degradation, the line of the break merely giving a line of weakness, along which the surface-drainage might widen the valley. If, however, we only take an angle for the sides of the lake giving a moderate depth, the necessity for a fracture does not exist, and we recur to some process of mere erosion for the scooping of the hollow in which the water lies, that process having, I consider, been the long-continued grinding of the ice of the great glacier No. 3 of the Map.

The Lake of Zurich.—The Lake of Zurich runs from N.W. to S.E., across the average strike of the Miocene strata, which are much disturbed towards its eastern end. It is bounded by high hills, much scarred by the weather, on which the different Miocene strata often stand out in successive horizontal steps. The Linth Canal and the Wallen See lie in an eastern prolongation of this valley, which is still further extended to the valley of the Upper Rhine at Sargans. The lake is about 25 English miles in length, by $2\frac{1}{4}$ wide in its broadest part. A great moraine partly dams it up at its outflow at Zurich; and a second forms the shallow at Rapperswyl, where the lake is crossed by a long wooden bridge. The general level of the water is 1341 feet above the sea, and only about 639 deep; and the bottom of the lake is therefore 702 feet above the sea. The limestone rocks at Baden, on the Limat, are 1226 feet above the sea; and the lake therefore lies in a true rock-basin, though it is probable that the old moraine at Zurich accounts for the retention of the water of the lake at its precise level. The long hollow was in old times entirely filled by the great glacier (No. 4 in the Map, Pl. VIII.) which descended from the mountains between the Todi and the Trinserhorn, through the valley of the Linth, to Baden.

The Wallen See.—The Wallen See lies in a deep valley, whose cliffy slopes of Secondary rocks rise from 2000 to 3000 feet, and in the Leistkamm 4500 feet above the surface of the lake. The lake itself is 1391 feet above the sea; and from the great steepness of its banks it may be inferred that it is exceedingly deep, but none of the authorities I have consulted give its soundings. A large branch from the great Rhine glacier (No. 5 on the Map) joined that of the valley of Glarus and Zurich through this wide gorge, and ground out the hollow of the Wallen See.

The Lake of Constance.—The Lake of Constance, the largest sheet of water in Switzerland, is about 50 miles in length, by about 15 in breadth at its broadest part. It is entirely surrounded by Miocene strata, often considerably disturbed, and forming great hills towards the S.E., which in a remarkable manner evince all the signs of long-continued erosion by running water,—conveying the impression that chiefly by that means all the deep valleys of the district have been worn since the close of the Miocene epoch. This lake lies 1298 feet above the sea; and, its depth being 912 feet, its bottom is only 386 feet above the sea. The falls of the Rhine are 1247 feet above the sea; and the lake therefore lies in an unmistakeable rock-basin, the whole of which was once overflowed by the deep and broad-spreading glacier of the Upper Rhine valleys (No. 5 of the Map), which stretched far northward beyond the lake into Baden and Wurtemberg. Being of greatest thickness where it entered the region of the lake, by its enormous weight and grinding power it scooped out, in the soft rocks below, the wide hollow now filled with water.

The Italian Lakes.—If we now turn to the Italian side of the Alps, we shall find the same phenomena prevailing in the Lakes of Maggiore, Lugano, and Como, the only important lakes I have yet had an opportunity of seeing south of the great chain. To each of these the same reasoning applies, modified only in detail; and I shall therefore briefly pass them over.

The most westerly, the Lago Maggiore, lies in a winding valley, 40 miles long, excavated in gneissic and jurassic rocks, which rise on either side in lofty mountains. The surface of the lake is 685 feet above the level of the sea, and near the Borromean Islands it has the enormous depth of 2625 feet; so that its bottom is 1940 feet lower than the sea-level. It must, therefore, be enclosed all round by rocks, unless we suppose the narrow passage at Arona, near its outlet, to be as deep as its deepest part, or that the alluvial deposits of the Ticino and the Po are more than 1940 feet deep—an assumption no one is likely to make.

Of all the Alpine lakes, that of Lugano is the most irregular in form,—in the language of M. Desor, stretching its arms like a great polyp among the mountains in all directions *. Its surface is 938 feet above the level of the sea, and its depth 515 feet. Its bottom is therefore only 410 feet above the sea-level, and the shape of the surrounding ground renders it impossible to believe that it is not entirely surrounded by rocks.

The Lake of Como, the hollow of which has been scooped out gene-

* See memoirs "De la Physionomie des Lacs Suisses" (extrait de la 'Revue Suisse,' 1860) and "Quelques Considérations sur la Classification des Lacs, à propos des bassins du revers méridional des Alpes," by E. Desor. The opinions of M. Desor and my own do not agree on the question of the origin of the lake-basins of the Alps. His views are well expounded in the above-named memoirs. It was in conversation with my friend, in 1860, that I first proposed what I consider the true solution of the question, and to this conversation I presume he alludes in the latter memoir, p. 13.—"On a prétendu que les lacs étaient l'effet de l'affouillement des glaciers qui auraient labouré le sol sur lequel ils s'avançaient," &c.

rally in the same set of rocks as the other two lakes, is 700 feet above the sea, and 1929 feet deep; and its bottom is therefore 1229 feet below the level of the sea. On the borders of these lakes the rounded rocks and the well-known glacier-stranded boulders, high on the mountain-sides, attest that these deep valleys were filled to the brim by a vast system of glaciers (Nos. 6 and 7 of the Map, Pl. VIII.) that flowed southerly from the snow-shed that runs from the eastern side of Monte Rosa, by the Rheinwald-horn, to the top of the valley of the Adda,—a system of glaciers so large that, like that of Aosta and Ivrea (No. 8 of the Map), further west, they protruded their ends and deposited their moraines far south on the plains of Piedmont and Lombardy.

The glacier of Ivrea (No. 8 on the Map), when it escaped from the valley of the Doire, deposited a moraine at its side, east of the town of Ivrea, rising in mere *débris* 1500 feet above the plain, and spreading out eastward in a succession of fan-shaped ridges miles in width. The vastness of this mass gives a fair idea of the huge size of the glacier, and of the great length of time it must have endured; and just as this glacier hollowed out the little rock-basins in which lie the tarns that nestle among the large *roches moutonnées* between the town and the moraine *, so, deep as the hollows of the great Lakes of Maggiore and Como are, I believe they also were scooped out by the grinding power of long-enduring ice, where, under favourable circumstances, the glaciers were confined between the mountains, and therefore thicker than the glacier of Ivrea where it debouched on the plain. Diagrams illustrative of this subject should be drawn on a true scale; otherwise, height, depth, and steepness being exaggerated, the argument becomes vitiated. I have not the data for giving an actual outline of the bottom of the Lago Maggiore; but a line drawn from the upper end of the lake to the required depth near the Borromean Islands gives *an angle only of about* 3° *in a distance of about* 25 *miles*, and from thence to the lower end of the lake (12 or 13 miles) *of about* 5°. The depths of Maggiore and Como do not, in my opinion, militate against my view; for, if the theory be true, depth is a mere indicator of time and vertical pressure in a narrow space. It is interesting, and confirmatory of this view, that the deepest part of the Lago Maggiore is just at the point where the enormous glacier of the Val d'Ossola joined the great ice-stream that was formed by the united glacier-drainage of the valleys above Bellinzona and Locarno. Where these glaciers united, there the lake begins; and where the ice was on the largest scale near the Borromean Islands, there the lake is deepest.

Summary with regard to the Alpine Lakes.—And now, in reviewing the subject of the origin of the lakes of Switzerland and North Italy, I would remark—

1st. That each of the great lakes (see Map) lies in an area once covered by a vast glacier. There is, therefore, a connexion between them which can scarcely be accidental.

* There are other well-known lakes dammed up by the moraine of this great glacier.

2nd. I think the theory of an area of *special subsidence* for each lake untenable, seeing no more proof for it in the case of the larger lakes than for the hundreds of tarns in perfect rock-basins common to all glacier-countries, present or past, and the connexion of which with diminished or vanished glaciers I proved originally in 'The Old Glaciers of North Wales.' In the Alps there is a gradation in size between the small mountain-tarns and the larger lakes.

3rd. None of them lie in lines of *gaping fracture*. If old fractures ran in the lines of the lakes or of other valleys, and gave a tendency to lines of drainage, they are nevertheless, in the deep-seated strata, exposed to us as close fractures now, and the valleys are valleys of erosion and true denudation.

4th. They are none of them in simple synclinal basins, formed by the mere disturbance of the strata after the close of the Miocene epoch: nor,

5th, Do they lie in hollows of common watery erosion; for running water and the still water of deep lakes can neither of them excavate profound basin-shaped hollows. So deeply did Playfair, the exponent of the Huttonian theory, feel this truth, that he was fain to liken the Lake of Geneva to the petty pools on the New Red Marl of Cheshire, and to suppose that the hollow of the lake had been formed by the dissolution and escape of salts contained in the strata below.

6th. But one other agency remains—that of ice, which, from the vast size of the glaciers, we are certain must have exercised a powerful erosive agency. It required a solid body, grinding steadily and powerfully in direct and heavy contact with and across the rocks, to scoop out deep hollows, the situations of which might either be determined by unequal hardness of the rocks, by extra weight of ice in special places, or by accidental circumstances, the clue to which is lost, from our inability perfectly to reconstruct the original forms of the glaciers.

7th. It thus follows that, valleys having existed giving a direction to the flow of the glaciers ere they protruded on the low country between the Alps and the Jura, these valleys and parts of the plain, by the weight and grinding power of ice in motion, were modified in form, part of that modification consisting in the excavation of the lake-basins under review.

In connexion with this point, it is worthy of remark that glaciers, many of them very large in the modern sense of the term, on the south side of the Vallais (excepting those of Mont Blanc), and the large glaciers on the south side of the Oberland, all drain into the Lake of Geneva; those on the north of the last-named snow-field, also large glaciers, are drained through the Lakes of Brienz and Thun. These, among the largest existing glaciers of the Alps, are only the shrunken tributaries of the greater glaciers that in old times filled and scooped out the basins of the lakes. The rest of the lakes, as already stated, are in equally close connexion with the old snow-drainage of glacier-regions on the grandest scale,—all of them, excepting those of Neuchâtel, Bienne, and Morat, lying in the direct

course of glaciers filling valleys that extend right into the heart of the mountains.

8th. Most of the lakes are broad or deep according to the size of the glaciers that flowed through the valleys in which they lie, this general result being modified according to the nature of the rock and the form of the ground over which the glacier passed. Thus, the long and broad Lake of Geneva, scooped in the Miocene lowlands, is 984 feet deep, and over its area once spread the broad glacier of the Rhone. Its great breadth and its depth evince the size of the glacier that overflowed its hollow. The Lake of Constance, lying in the same strata, and equally large, is 935 feet deep, and was overspread by the equally magnificent glacier of the Upper Rhine. The Lakes of Maggiore and Como, deepest of all, lie in the narrow valleys of the harder Secondary rocks of the older Alps; and the bottom of the first is 1992 feet, and the latter 1043 feet, below the sea-level. Both of these lie within the bounds of that prodigious system of glaciers that descended from the east side of the Pennine Alps and the great ranges north and south of the Val Tellina, and shed their moraines in the plains of Piedmont and Lombardy. The depth of the lakes corresponds to the vast size and vertical pressure of the glaciers. The circumstance that these lakes are deeper than the level of the sea does not affect the question, for we know nothing about the absolute height of the land during the Glacial period.

The Lakes of Thun and Brienz form part of one great hollow, more than 2000 feet deep in its eastern part, or nearly 300 feet below the level of the sea. They lie in the course of the ancient glacier of the Aar, the top of which, as *roches moutonnées* and striations show, rose to the very crests of the mountains between Meyringen and the Grimsel.

The Lake of the Four Cantons is imperfectly estimated at only 884 feet in depth; but here we must also take into account the great height and steep inclines of the mountains at its sides. The Lake of Zug, 1311 feet deep, lies in the course of the same great glacier, the gathering-grounds of which were the slopes that bound the tributaries of the Upper Reuss and the immense amphitheatre of the Urseren Thal, bounded by the Kroutlet, the Sustenhorn, the Galenstock, the St. Gothard, and the southern flanks of the Scheerhorn.

The lesser depths (660 feet) of the Lake of Zurich were hollowed by the smaller but still large glacier that descended the valley of the Linth.

This completes the evidence.

Lakes of the Northern Hemisphere generally.—I shall now make a few remarks on the bearing of this subject on the glacial question generally.

It is remarkable that in Europe and North America, *going northward*, lakes become so exceedingly numerous, that I have been led to suppose the existence of some intimate connexion between their numbers and the northern latitudes in which they occur.

Let any one examine the map of North America, and he will

find that, from the Atlantic coast to the St. Lawrence, through New Hampshire, Vermont, the north of the State of New York, Maine, Nova Scotia, New Brunswick, Gaspé, and Newfoundland, the whole continent is strewn with lakes. North of the St. Lawrence and the great lakes, as far as the Arctic Ocean, the same sprinkling of unnumbered lakes over the entire face of the country is even more remarkable; and it is a curious circumstance that a large part of this vast area is so low and undulating, that some of its lakes drain two ways—towards the North Sea and the Gulf of Mexico, or towards the North Sea and the North Atlantic. This vast country, about as far south as lat. 40°, shows, almost universally, marked signs of the strongest glacial action, in the *moutonnée* forms, polish, and constantly recurring striation of the rocks. I have only seen a few of the above-mentioned lakes south of Lake Ontario; but I have closely questioned that able observer, Dr. Hector, who has examined the country north and west of the great American lakes, and he informs me that, though unable to account for it, he was struck with the circumstance that so many (he thought he might say *all*) of the smaller lakes are in *rock-basins*. I connect this circumstance with the universal glaciation of the country, still evinced on the grandest possible scale by every sign of ancient ice. These signs, I now believe, are far too universal and unvarying in their general directions to have been produced merely by floating ice, though in part of the glacial history of the continent floating ice has undoubtedly left large traces. But the lake-basins could only, I believe, have been scooped out by true continental glacier-ice, like that of Greenland; for the lakes are universal in all the ice-worn region *.

On the eastern side of the Atlantic, Wales, Cumberland, many parts of Ireland, the North Highlands, and some of the Western Isles are also dotted with unnumbered lakes and tarns. All of these are well-glaciated countries, both high and low; and for Wales and many parts of Scotland, I can answer that by far the greater proportion of these lakes lie in rock-basins of truly glacial origin †.

* Since this memoir was written, I have conversed on the subject with Sir Wm. Logan, Director of the Geological Survey of Canada, who not only agrees in my views with respect to the origin of American lakes in general, but also believes that the great American lake-basins may have been scooped out by the same means. They are all true rock-basins, in areas occupied by comparatively soft rocks surrounded by harder strata. Given sufficient time, I see no difficulty in this view, to which I inclined while writing this paper, but refrained from stating it, considering that most readers would think it too strong, and thus that in general opinion I might damage the whole theory. Sir William says that the arrangement of the strata proves that the great lakes do not lie in areas of special subsidence.

† See 'The Old Glaciers of North Wales.' When I published my account of these glaciers, I was too timid to include the Lakes of Llanberis, Llyn Ogwen, Llyn Cwellyn, and some others of the larger lakes in this category. I now feel convinced that they are true rock-basins, and also that the shallower pools of Llyn Llegeirin, Llyn Felin-y-nant, and others in Anglesea had the same origin. The horizontal striations far up the side of Carnedd Dafydd, by Llyn Ogwen, were probably made by a glacier of immense thickness during the first great glacier-period, preceding the deposition of the stratified drift.

Loch Lomond and Loch Katrine, probably, like the greater lakes of Switzerland, are of the same kind, being merely large cases of glacier-erosion, though in the case of the former it may be that the alluvial deposits on the banks of the Leven prevent its being invaded by the tide. Its islands are mere *roches moutonnées* *.

In the lowlands of Scotland numerous examples of the same kind of rock-basins occur, some of them certain, others doubtful because of the surrounding drift, which indeed in some cases may be the sole cause of the retention of the water. Notable examples of both kinds occur in the lowlands of Fife and Kinross, and of true rock-basins in the Cleish and Ochil Hills, as for instance Loch Glow, Dow Loch, and the two Black Lochs, and more doubtfully Loch Lindores.

I have not yet had an opportunity of visiting the Scandinavian peninsula, which, geologists are aware, is, through all its length and breadth, one of the most wonderfully glaciated countries in the world. On the west, descending from the great chain, striated *roches moutonnées* plunge right under the deep fiords; and on the east, in Sweden, all between the mountains and the Baltic, round the Gulfs of Bothnia and Finland, and up to the North Sea, the whole country is covered with a prodigious number of lakes, just like North America, the Lewes, and the North Highlands of Scotland. The intense glaciation which all of these countries have undergone, their similarity, and what I believe to be the intimate connexion of such crowded lakes with the movement of ice, induce me to believe that in Sweden also a great number of the lake-hollows must be true rock-basins scooped out by the passage of glacier-ice into the Baltic area. Furthermore, as the glaciated sides and bottoms of the Norwegian fiords and of the saltwater lochs of Scotland seem to prove, each of these arms of the sea is merely the prolongation of a valley down which a glacier flowed, and was itself filled with a glacier; for the whole country was evidently, like the north of Greenland, moulded by ice. In parts of Scotland, some of these lochs being deeper in places than the neighbouring open sea, I incline to attribute this depth to the grinding power of the ice that of old flowed down the valleys, when possibly the land may have been higher than at present†. It may, however, only arise from unequal deposition of detritus. If the former view be admitted, raise the land so as to lay bare the surrounding ocean-bottom, and in some respects of levels and depth they become approximately the counterparts of the deeper narrow lakes of Switzerland and North Italy, glaciers bounded by mountains having flowed through both, and debouched upon the plains beyond.

The Glacial Theory.—Furthermore, considering the vast areas over which the phenomena described are common in North America and Europe, I believe that this theory of the origin of lake-rock-basins

* When the lake was low, I have seen in Loch Lomond ice-striated surfaces of rock just above the water, the striations running in the direction of the length of the lake.

† But this is not essential, unless the lochs are so deep that the ice must have been floated up before reaching the deeper parts.

is an important point, in addition to previous knowledge, towards the solution of the glacial theory; for I do not see that these hollows can in any way be accounted for by the hypothesis that they were scooped by floating ice*. An iceberg that could float over the margin of a deep hollow would not touch the deeper recesses of the bottom. I am therefore constrained to return, at least in part, to the theory many years ago strongly advocated by Agassiz, that, in the period of extremest cold of the Glacial epoch, great part of North America, the north of the Continent of Europe, great part of Britain, Ireland, and the Western Isles†, were covered by sheets of true glacier-ice in motion, which moulded the whole surface of the country, and in favourable places scooped out depressions that subsequently became lakes.

This was effected by the great original glaciers (probably connected with the origin of the *unstratified* boulder-clay) referred to in my memoir on the glaciers of North Wales‡, but the magnitude of which I did not then sufficiently estimate. The cold, however, continued during the depression of North Wales and other districts beneath the sea, when they received the *stratified* erratic drift; and glaciers not only did not cease at this time of depression, but were again enlarged during the emergence of North Wales and other countries, so as to plough the drift out of many valleys. These enlarged glaciers, however, bore no comparison in size to the great original sheets of ice that converted the North of Europe and America into a country like North Greenland. The newer development of glaciers was strictly local. Amelioration of climate had already far advanced, and probably the gigantic glaciers of Old Switzerland were shrinking into the mountain-valleys.

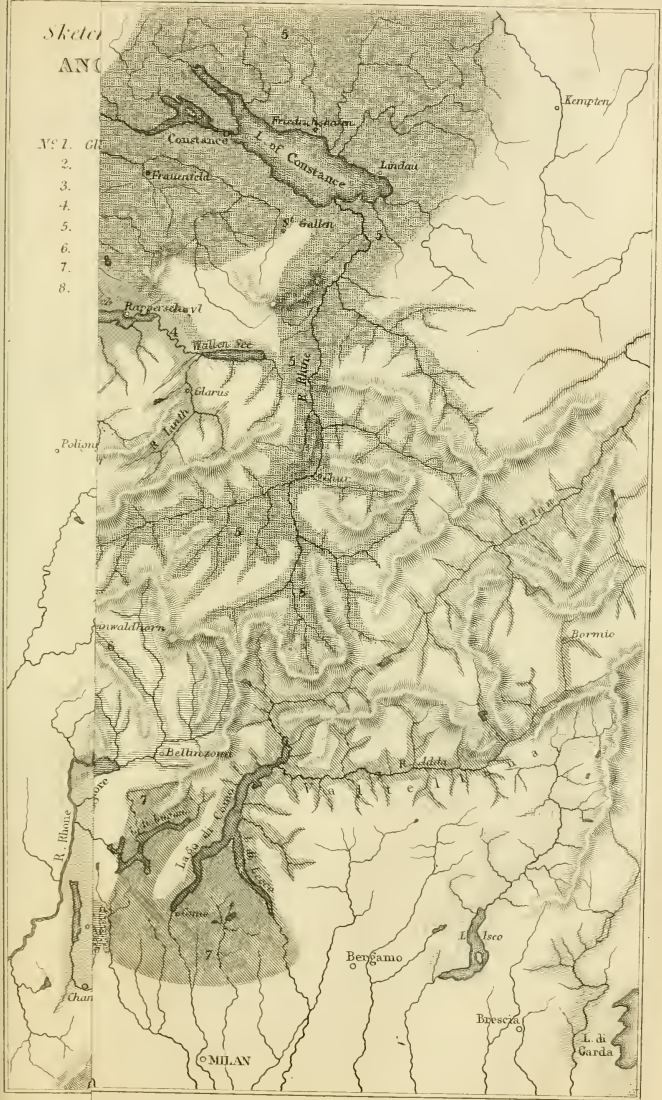
Finally, if this be true, I find it difficult to believe that the change of climate that put an end to this could be brought about by mere changes of physical geography§. The change is too large and too universal, having extended alike over the lowlands of the Northern and the Southern Hemispheres. The shrunken or vanished ice of mountain-ranges is indeed equally characteristic of the Himalaya, the Lebanon, the Alps, the Scandinavian chain, the great chains of North and South America, and of other minor ranges and clusters of mountains like those of Britain and Ireland, the Black Forest, and the Vosges.

* I do not in any way wish to deny that much of the glaciation of the lower countries that came within the limits of the Drift was effected by floating ice on a large scale, which must have both polished and striated the rocks along which it ground. I have, with other authors, described this in various memoirs. But the two sets of phenomena are distinct.

† The Lewes is covered by small lakes.

‡ Quart. Journ. Geol. Soc. vol. xviii. p. 371.

§ It has been suggested to me by Dr. Sibson that the prodigious waste of the Alps by the gradual disintegration and diminution of the upper snow-fields, witnessed by the great moraines of North Italy and other phenomena, must have tended to lessen the glaciers. This is true, but, as he also believes, it is not of itself enough to account for the shrinking of the ice into the higher valleys where it is now alone found.



J.W. Lowry feulp.